# TIME-SERIES ANALYSIS OF SWEDISH CENTRAL BANK'S INTEREST RATE OPERATION RULE

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## ABSTRACT

*This paper estimates a forward-looking Taylor-type interest rate reaction function for Swedish central bank's inflation-targeting policy and a developed model with the exchange rate taken into account. Based on real-time quarterly macroeconomic time-series from Sweden in the first decade of this century, The evidence suggests that the Swedish central bank, Sveriges Riksbank, was not merely adjusting its repo rate in response to the changes in expected inflation and output deviations. An approach that is known as one of a central bank's classic regulation tools to deal with domestic inflation first proposed by economist John Taylor. The results show that the targeted exchange rate could be Sveriges Riksbank's third policy concern in real practice, though in an extraordinarily implicit way. Swedish central bank's underlying emphasis upon exchange rate stability may shed light on why the inflation record of Sweden in the recent years missed its monetary policy objective. However, the argument that unyielding exercise of the classic Taylor Rule would enhance policy effectiveness in a small open country like Sweden remains in question.*

**JEL:** C32; E52; E58; G28

**KEYWORDS:** Exchange Rate, Inflation, Monetary Policy, Taylor Rule

## INTRODUCTION

Sweden abandoned a fixed exchange rate regime in 1992 due to the unruly fluctuation of domestic prices and wage rates between the 1970s and 1990s (Svensson, 1995; Andersson et al., 1995; Almekinders, 1995; Giavazzi et al., 2006). Ever since, Central Bank of Sweden (Sveriges Riksbank), the oldest central bank in the world, sanctified its new monetary policy that aims at a low and stable domestic price level. Sweden became the fourth country in the world, following New Zealand, Canada and the UK (McCallum, 1996) to regulate its monetary instruments in order to achieve and maintain a clearly set inflation rate target of 2% with an acceptable range from 1% to 3%. Although statistics show that inflation in Sweden thereafter shrank to a reasonably lower level relative to a record of over 5% in terms of annualized CPI prior to the 1990s, Sweden was still considered unsuccessful in harnessing the drastic volatility of inflation (McCallum, 1996). Even though inflation was far from being controlled, to what extent did this updated practice enhanced Swedish central bank's capability of controlling inflation?

This paper attempts to explore whether this straightforward inflation-targeting monetary policy strategy accounted for the improved inflation condition. In addition, particular attention is given to the investigation a new floating exchange rate regime could have played an unconstructive role in the Swedish central bank's efforts to counterstrike inflation.

The paper is structured as follows. The following section discusses the relevant literature. In Section 3, the baseline Taylor-type interest rate reaction model is introduced, followed by an expanded model that incorporates the exchange rate variable. Section 4 proceeds with the differentiation between the use of real-time data and ex-post data. Then the dataset and a statistical description of the major macroeconomic time-series of Sweden during the sample period are illustrated. In Section 5, the estimation results are presented, which offer us insights on how we understand that Swedish central bank was subtly responding to the exchange rate variation as its third concern. Section 6 concludes and identifies the extensions of interest for further research.

## LITERATURE REVIEW

A wide range of contemporary literature advocates a Taylor Rule standard as a classic model from which a number of central banks had gained valuable policy inferences for their own inflation regulation purposes (Judd et al., 1998; Clarida et al. 1999; Woodford 2001). The Taylor Rule (Taylor, 1003b) for monetary policy refers to a central bank's policy practice of adjusting short-term nominal interest rates in response to inflation and output deviations. Empirically, Taylor's Rule has proved efficient in mitigating inflation in a variety of countries (Taylor, 1993a; Clarida et al. 1999; Woodford 2001). Given that Sweden had successfully reduced its increasing price pressure after adopting an explicit inflation-targeting policy, this paper attempts to verify whether Sveriges Riksbank's regulations to deal with inflation are a typical implementation example of the Taylor-Type interest rate reaction rule.

Taylor (1993b) also argues that the short-term interest rate reaction rule could be more effective as it is performed under a floating exchange rate regime than a peg system. Since inflation deviation and the production gap in the former situation should be comparatively smaller, a moderate adjustment of interest rates could achieve the goal to moderate inflation and output while preventing such regulation from incurring further economic malfunctions (Taylor, 1993b). The exchange rate difference could complicate the evaluation of Taylor Rule effectiveness. However, scarce attention has been directed to the understanding of central banks' regulation behaviors in small open economies such as Sweden. These small economies largely depend exchange rate regime function sound trade. Moreover the effect of a shift from fixed to floating exchange regime on domestic inflation control remains unclear. Maslowska(2009) analyzes Swedish quarterly data from 1990s to 2000s and concludes that Sveriges Riksbank adjusted its short term interest rate in response to inflation and GDP gaps. Nonetheless, his findings could be gratuitous as he does not take the exchange rate regime change into account and fails to make it clear why his two parametric estimations of the interest rate response strengths for inflation and output deviations are not robust.

Other studies maintain that central banks are not restrained by the conditions set by Taylor's formula to manipulate inflation (Poole, 2007). Central Bank of Germany (Bundesbank) is an example of non-Taylor Type regulation from 1970s to 1998. During this time it treated domestic money growth as a third benchmark, in addition to inflation and output deviations, to make decisions onshort term interest rate adjustments (Gerberding et al., 2005). How well the exchange rate condition might be used for Swedish central bank's discretion on interest rate adjustment is an interesting avenue for research. This goal of this paper is to detect the existence of the Taylor-type interest rate reaction rule for inflation control in Sweden. Further the paper examines whether exchange rate volatility affects the effectiveness of inflation targeting policy when Sweden transited into the floating exchange rate regime.

## METHOD OF MODELING AND ESTIMATION

To approach the two empirical research questions stated in Section 1, two hypotheses are forwarded. First, Sveriges Riksbank adjusted its interest rate for inflation control in sole response to the deviation of the domestic price level and output gap. Second, the real practice of Swedish central bank's interest rate maneuver treated exchange rate volatility as an extra consideration in order to achieve a precise inflation peg. As an econometric approach, the two tests are performed through the estimation of two models that are developed from the fundamental Taylor-type interest rate reaction function as shown below:

$$i = \pi + 0.5\,\hat{y} + 0.5(\pi - 2) + 2 \quad (1)$$

Taylor (1993b) originally used this simple function form to model the reactions of the United States federal funds rate in the last century towards domestic inflation. The notation is as follows: $i$ denotes the nominal federal funds rate, $\pi$ is the previous yearly inflation rate and $\hat{y}$ represents the real output deviation from a log linear production trend in percentage. It is worth noting that Taylor did not model inflation in a forward-looking manner but adopted the lagged rate as a proxy and thus the function is backward looking in nature. Moreover, the constant "2" is in a percentage point unit denoting the US inflation rate in equilibrium and simultaneously the real rate of interest in the long run. By this model, the nominal interest rate would be four if there is no output gap and the inflation rate hits its long-run target.

Though Taylor did not estimate his model himself (Judd et al., 1998), he did assign two values 1.5 and 0.5 as the parametric estimates of $\pi$ and $\hat{y}$, which respectively measure the US federal funds rate's strength of responses to the inflation level and production deviation. Such a reaction function provides a good fit of the US data during the period of 1987-1992 (Taylor, 1993b). However, since central banks worldwide published their own forecast data based on which monetary policy decision are made (Chortareas et al., 2002), research models the interest rate reaction in a forward-looking fashion (Clarida et al., 1997; Gerberding et al., 2005). Following this tradition, a Taylor-type model is developed with the expectation operators in certain anticipation horizons in the setting of Sweden:

$$i_t^* = \varphi_y E_t(\tilde{y}_{t+n_1}|\Omega_t) + \varphi_\pi E_t[(\pi_{t+n_2} - \pi^*)|\Omega_t] + \check{r} \qquad (2)$$

*Where:*

*$i_t^*$ = Sveriges Riksbank's nominal interest rate target at period t*
*$\pi^*$= 2%, Swedish central bank's official time-invariant inflation target*

$E_t(\tilde{y}_{t+n_1}|\Omega_t)$ = *Expected real output gap, the difference of expected real GDP and the production potential, which is divided by the potential given the set $\Omega_t$ of all the information available at period t with an expectation horizon of $n_1$ periods ahead*

$E_t[(\pi_{t+n_2} - \pi^*)|\Omega_t]$ = *Anticipated deviation of inflation from the policy target with $n_2$ horizons based on all the information available at t*

$\check{r}$ = *Long-run equilibrium real interest rate*

In line with the empirical literature (Judd et al., 1998; Orphanides, 2004; Aleksandra, 2009), one-year and four-year forecast horizons $n_1$ and $n_2$ are set at 1 and 4. Eq.(2) implies that to achieve the long-run equilibrium real rate of interest, Swedish central bank would set a short-term nominal interest rate target at each decision period in response to both the forecasted departures in output and inflation based on all the information at hand at any given period t. This method of modeling mirrors Sveriges Riksbank's policy statement of a monetary policy targeting a manageable inflation bandwidth from 1% to 3%. Hence, the strengths of Swedish central bank's reactions to the two dimensions of deviation are measured by the estimates of two non-negative coefficients $\varphi_y$ and $\varphi_\pi$.

Next, following Clarida et al. (1997) and Gerberding et al. (2005), assume that the actual nominal interest rate is partially adjusted to its target at each period, which can be modeled by a smoothing parameter $\rho \in [0,1]$ in a Error Correction Model (ECM) format:

$$i_t = (1-\rho)i_t^* + \rho i_{t-1} + v_t \qquad (3)$$

Here, as a pure white noise, an exogenous shock $v_t$ to the actual short-term nominal interest rate $i_t$ is introduced. Taking the partial-adaptation of nominal interest rate into account, substitute Eq.(2) into (3) and the entire model is reorganized as:

$$i_t = (1-\rho)\check{r} + (1-\rho)\varphi_y E_t(\tilde{y}_{t+1}|\Omega_t) + (1-\rho)\varphi_\pi E_t[(\pi_{t+4} - \pi^*)|\Omega_t] + \rho i_{t-1} + v_t \quad (4)$$

The inconsistent method of producing forecasts applied in a time-series dataset may create systematic bias in the analysis of such data (Carnot et al., 2005). However, it is not easy to obtain the original forecasted series used by Riksbank to make the specific interest rate adjustment decisions. Clarida et al. (2005) suggest that this type of reaction model despite being formatted in expectation operators, may be rewritten in terms of the realized values of variables. Doing so would help minimize potential errors by directly using the raw forecasted data. Accordingly, Eq. (4) is rearranged into a system as follows:

$$i_t = \alpha + (1-\rho)\varphi_y \tilde{y}_{t+1} + (1-\rho)\varphi_\pi \pi_{t+4} + \rho i_{t-1} + \varepsilon_t \quad (5)$$
$$\alpha = (1-\rho)(\check{r} - \varphi_\pi \pi^*) \quad (5a)$$
$$\varepsilon_t = -(1-\rho)\varphi_y[\tilde{y}_{t+1} - E_t(\tilde{y}_{t+1}|\Omega_t)] - (1-\rho)\varphi_\pi[\pi_{t+4} - E_t(\pi_{t+4}|\Omega_t)] + v_t \quad (5b)$$

This system condenses forecasting errors of the output and inflation gaps into a disturbance term $\varepsilon_t$. To ensure the validity of estimation, the errors of forecasts must not exhibit serial autocorrelation and not be consistently biased (Greene, 2008). Consistent with the findings of Clarida et al. (1997), Smant (2002) and Gerberding et al. (2005), the ACF (Autocorrelation Function) and PACF (Partial Autocorrelation Function) test results, not reported here, also indicate that non-stationarity issues are not present. Therefore, no differencing of Eq. (5) is required to guarantee stationarity. It is an I(0) process. In addition, serial correlation-robust standard errors and Durbin-Watson statistics are presented indicating a suitable model. To lend more credence to this argument, the use of real-time data would further mitigate estimable forecast errors and accumulation bias across different periods.

The endogeneity bias of explanatory variables could affect estimation validity. As a linear combination of the forecast errors and the white noise interest rate shock, the distribution of the disturbance term may not be orthogonal of the regressors. A classic solution is to incorporate selected instruments into the estimation to correct this bias (Ahn, 1995). In this paper, variables with lagged values is adopted as instruments, which might be associated with output gap and inflation fluctuation but not correlated with the interest rate shock and not contribute to the forecasting error. To better assess this use of instruments, Hansen's J statistic is reported. The uncertainty of the exact error term form also implies the possibility of heteroskedasticity that would nullify the consistency of estimates obtained though instrumental variable regression (Baum et al., 2003). A more effective estimation approach, the Generalized Method of Moments (GMM) technique, is employed in this paper consistent with Clarida et al. (1997) and Gerberding et al. (2005) to adjust for heteroskedasticity problems. The Barlett Kernal option is selected for the GMM-Time series estimation and a fixed bandwidth recommended by the Newey and West Principle is chosen.

To test whether there is significant impact of exchange rate volatility on the responsiveness of interest rates in Sweden, the forward-looking model Eq. (5) can be expanded into the following system:

$$i_t = \gamma + (1-\rho)\varphi_y \tilde{y}_{t+1} + (1-\rho)\varphi_\pi \pi_{t+4} + (1-\rho)\varphi_e e_{t+1} + \rho i_{t-1} + \mu_t \quad (6)$$
$$\gamma = (1-\rho)(\check{r} - \varphi_\pi \pi^* - \varphi_e e^*) \quad (6a)$$
$$\mu_t = -(1-\rho)\varphi_y[\tilde{y}_{t+1} - E_t(\tilde{y}_{t+1}|\Omega_t)] - (1-\rho)\varphi_\pi[\pi_{t+4} - E_t(\pi_{t+4}|\Omega_t)]$$
$$-(1-\rho)\varphi_e[e_{t+1} - E_t[(e_{t+1}|\Omega_t)] + v_t \quad (6b)$$

It incorporates a similar "deviation" term for the exchange rate by assuming that the exchange rate follows a mean reversion track as supported by Lindberg et al.'s findings on the evolutionary path of Swedish exchange rates (1994). The mean of the exchange rate sample can be used as "target" to model the assumed mean reversion behaviors. Since our sole focus is on whether the motion of exchange rate change might have induced the central bank to alter its interest rate as a response, the use of this sample mean should not dramatically affect the significance of the null hypothesis test.

If the null hypothesis that the adjustment of interest rate does not respond to the expected deviation of the exchange rates one period ahead were rejected, it would lead to a safe conclusion that the forward-looking Taylor Rule may not properly account for real policy exercises in Sweden. Consequently, this expanded Taylor-type model would have greater explanatory power. Ultimately, the GMM estimate of the parameter set including $\{\alpha, \gamma, \varphi_y, \varphi_\pi, \varphi_e\}$ would deliver important information on whether Sveriges Riksbank's interest rate operations might have different strengths of response towards each of these possible deviations and how well the inflation control could have benefited from the manipulation.

## THE REAL-TIME DATASET

Orphanides (2004) holds that using ex-post data to estimate the Taylor Rule would be problematic since the updated information used to correct the existing data could be different from or even contrast with information available to central banks for making forecasts and decisions. However, applying initially published and barely revised data could not only minimize the forecast error, that is the deviation of the realized value from the official forecast, but also shape all the forecast errors in a consistent distribution (Orphanides, 2004). In line with Orphanides, this paper analyzes a real-time dataset, which is consisted of the most "up-to-date" data at previous points to best capture Sveriges Riksbank's past policy behaviors.

Data points in real-time time-series are subtracted from Riksbank's officially issued Monetary Policy Report, formerly the Inflation Report, which is published in February, July and December each year since 1993. This publication is the crucial reference for monetary policy decision-making as the Swedish central bank considers it "the background material for monetary policy decisions...when deciding on an appropriate monetary policy." However, since the release of the report occasionally deviates from its fixed publication periods, Sveriges Riksbank's press releases and an infrequently published document "Monetary Policy Updates" contribute missing data points.

According to the two models, major variables include the short-term nominal interest rate, output gap, inflation rate and exchange rate. In May, 1994, the Swedish repo rate became the most important instrument for the short-term interest rates. The repo rate in percentage is thus used in this paper. Unfortunately, the earliest issue of the Monetary Policy Report that reports the real-time output gap data was in July of 2001. This implies that the time series dataset would start from July 2001. Moreover, as the estimated output gap was reported quarterly, all the frequency other variables should be quarterly manner. Sveriges Riksbank estimated the domestic output gap following a Hodrick and Prescott (HP) filtering method, which separates the long term output growth trend of GDP from fluctuations subject to the business cycle. The output gap data in this dataset is the percentage deviation of real GDP in expenditure from the production potential.

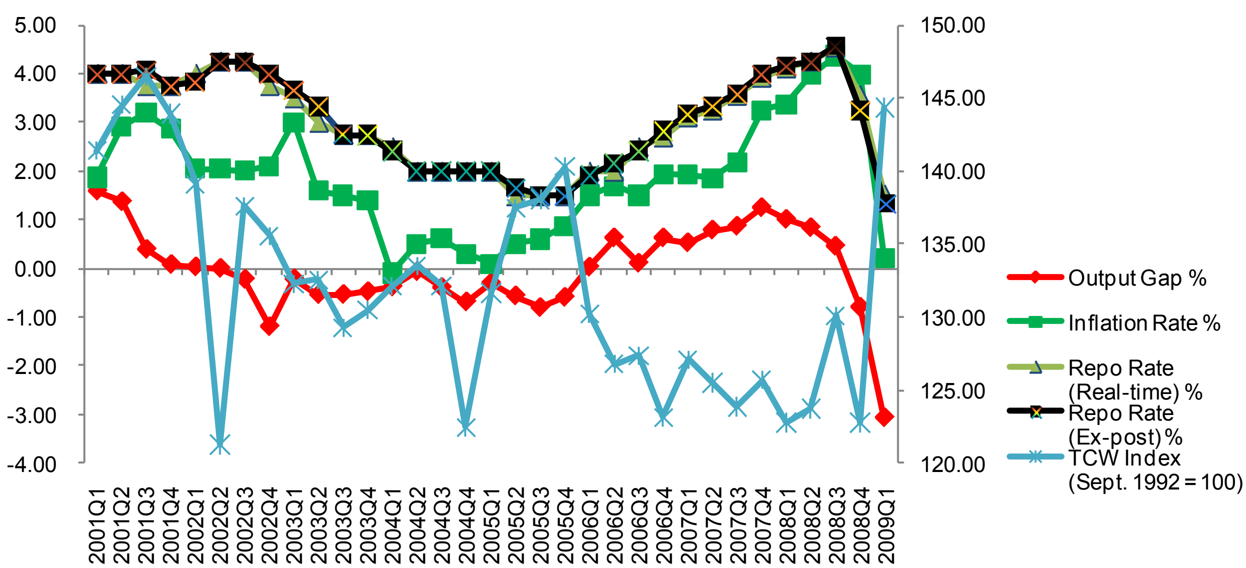
Among domestic price level measurements shown in reports, the annual percentage change of Consumer Price Index (CPI) is adopted, identified by the Riksbank as the standard inflation metric. The TCW index, SDR index, KIX index and Cross-rates are all indicators reflecting the strength of Swedish Krona against a group of comparison currencies.

The Total Competitiveness Weights (TCW) index of the Swedish Krona against a basket of other 21 currencies is chosen for analysis since this is the only exchange rate index that is consistently reported since the July 2001 report. Note that TCW has a benchmark of 100 representing the Krona strength in November 1992 when the Sweden abandoned its exchange rate peg and let the Krona start floating. A lower value of TCW amounts to a strengthened Krona.

The real-time data points are subtracted from the reports in the following way. Suppose the most recent statistics were published in one of the three issues of the Monetary Policy Report at a given quarter t and that fresh repo rate data, CPI index and TCW index of the last quarter t-1 can be located. Only closing data points of the third month of a given quarter (March, June, September and December) should be used. Real-time data for the 2003q4 observation can be found in the January 2004 issue. The data for 2004q1 and 2004 q2 could have been collected from the July report of 2004. The 2004q3 data is obtained from the December report of 2004. The most recent GDP gap data is reported with a two-quarter lag so only the realized output gap of quarter t-2 can be found in the quarter t issue. Based on all the relevant reports from the July 2001 to October 2009 issues, a premature sample containing 33 observations from 2001q1 to 2009q1 is established. The sample period dates from the time the output gap was available to the most recent report in which the GDP gap estimation was published.

The statistics for the GMM regression is also included. It contains the 2- and 4-quarter lagged values for the output gap and the 1 to 4 lagged values for CPI and TCW. In addition, the four lags of the natural logarithm of OECD crude oil price in US dollars are used to proxy the global price level. In line with Gerberding et al. (2005), 1 to 4 lagged values of the monetary aggregate annual growth rate are employed as well. Specifically, the M0 growth rate indicating the development trend of banknotes and coins in circulation is used since Sweden highly relies on cash transactions (Andersson et al., 2001). A graphical account of relevant economic time-series in Sweden is illustrated in Figure 1:

Figure 1: Visual Macroeconomic Statistics in Sweden: 2001Q1 – 2009Q1




*This figure shows how the real-time inflation rate, output gap and exchange rate were interacting with the evolutions of repo rates in Sweden.*

Figure 1 shows real-time and ex-post repo rates resembled each other except for slight deviations from 2002q4 to 2003q2. Further, Table 1 indicates the approximate 2% inflation rate target was achieved for 9/33 quarters and inflation was controlled within the acceptable bandwidth (1% to 3%) for 20/33 times. A disinflation snare lasted for about two years in 2004 and 2005. Thereafter, the Swedish economy faced increasing inflation pressure from the end of 2007 the first quarter of 2009.

It is clear that the exchange rate, TCW index, did not necessarily reveal an ostensible direction of movements but fluctuated between 147.5 and 122. It also exhibits an obvious depreciation trend of the Swedish Krona during the transition period from 2008 to 2009. Hence, is no visual evidence that implies its correlation with the repo rate development.

Table 1: Macroeconomic Account of Sweden: 2001Q1 – 2009Q1

| Quarter | Output Gap % | Inflation Rate % | Repo Rate (Real-time) % | Repo Rate (Ex-post) % | TCW Index (Sept. 1992 = 100) | Repo Rate (GMM Fitted) % |
|---|---|---|---|---|---|---|
| 2001Q1 | 1.58 | 1.87 | 4 | 4 | 141.41 | 3.86 |
| 2001Q3 | 0.38 | 3.2 | 3.75 | 4.08 | 146.49 | 3.77 |
| 2001Q4 | 0.07 | 2.87 | 3.75 | 3.75 | 143.94 | 3.78 |
| 2002Q1 | 0.03 | 2.046 | 4 | 3.83 | 139.11 | 4.02 |
| 2002Q2 | -0.01 | 2.05 | 4.25 | 4.25 | 121.28 | 3.95 |
| 2002Q3 | -0.23 | 2.01 | 4.25 | 4.25 | 137.59 | 3.85 |
| 2002Q4 | -1.20 | 2.1 | 3.75 | 4 | 135.57 | 3.80 |
| 2003Q1 | -0.22 | 3 | 3.5 | 3.67 | 132.30 | 3.56 |
| 2003Q2 | -0.54 | 1.6 | 3 | 3.33 | 132.58 | 3.43 |
| 2003Q3 | -0.54 | 1.5 | 2.75 | 2.75 | 129.31 | 3.31 |
| 2003Q4 | -0.48 | 1.391 | 2.75 | 2.75 | 130.48 | 3.15 |
| 2004Q1 | -0.39 | -0.1 | 2.5 | 2.42 | 132.13 | 2.98 |
| 2004Q2 | -0.07 | 0.5 | 2 | 2 | 133.51 | 2.87 |
| 2004Q3 | -0.40 | 0.61 | 2 | 2 | 132.13 | 2.82 |
| 2004Q4 | -0.69 | 0.3 | 2 | 2 | 122.47 | 2.77 |
| 2005Q1 | -0.31 | 0.1 | 2 | 2 | 131.66 | 2.74 |
| 2005Q2 | -0.57 | 0.5 | 1.5 | 1.67 | 137.49 | 2.72 |
| 2005Q3 | -0.81 | 0.6 | 1.5 | 1.5 | 138.09 | 2.67 |
| 2005Q4 | -0.60 | 0.88 | 1.5 | 1.5 | 140.32 | 2.78 |
| 2006Q1 | 0.02 | 1.5 | 2 | 1.92 | 130.24 | 2.92 |
| 2006Q2 | 0.62 | 1.7 | 2 | 2.17 | 126.78 | 3.03 |
| 2006Q3 | 0.10 | 1.5 | 2.5 | 2.42 | 127.35 | 3.22 |
| 2006Q4 | 0.62 | 1.94 | 2.7 | 2.83 | 123.13 | 3.50 |
| 2007Q1 | 0.52 | 1.92 | 3.11 | 3.17 | 127.09 | 3.81 |
| 2007Q2 | 0.78 | 1.86 | 3.25 | 3.33 | 125.50 | 4.18 |
| 2007Q3 | 0.86 | 2.19 | 3.55 | 3.58 | 123.86 | 4.59 |
| 2007Q4 | 1.24 | 3.25 | 3.92 | 4 | 125.67 | 4.94 |
| 2008Q1 | 1.00 | 3.38 | 4.11 | 4.17 | 122.78 | 4.80 |
| 2008Q2 | 0.83 | 3.98 | 4.25 | 4.25 | 123.71 | NA |
| 2008Q3 | 0.45 | 4.37 | 4.54 | 4.58 | 130.10 | NA |
| 2008Q4 | -0.80 | 3.99 | 3.56 | 3.25 | 122.76 | NA |
| 2009Q1 | -3.07 | 0.22 | 1.53 | 1.33 | 144.36 | NA |

*Data Sources: Statistics Sweden http://www.scb.se/ & Sveriges Riksbank Database http://www.riksbank.com/*

There exists a co-movement among the repo rates, output gaps and the inflation rates though the volatility of output gap is distinctively smaller than that of the former two variables. Another distinction is that during the last three quarters of 2008, output gap direction evolution contradicted that of the inflation rate and repo rate. There was dramatic economic volatility from 2008 to 2009, which makes the tentative GMM estimation results less than satisfactory. The unreported result implies that the specified models cannot capture this fluctuation since indicators including R-squared, Instrument Over-identifying Restriction, Durbin-Watson statistic would not render any statistical power if the observations covering the last three quarters of 2008 and the first quarter of 2009 were included in the regression. Eventually, these observations marked by severe volatility are dropped and the sample size shrinks to 29 observations. These outliers might be attributable to distorted impacts upon the Swedish economy that were brought by the worldwide economic instability. Updated theories are required to model these periods of volatility, and represent an interesting topic for future research.

## REGRESSION RESULTS AND INTERPRETATION

The GMM estimations of the two models that aim to capture the Swedish central bank's interest rate operations are based on the quarterly real-time time-series data. The sample is consisted of 29 observations from 2001q1 to 2008q1. Table 2 displays the estimation result of Sveriges Riksbank's interest rate reactions to the expected output and inflation deviations based on the baseline forward-looking Taylor-type model Eq. (5).

Table 2: GMM Estimation of the Baseline Model - Equation (5)

| **Coefficients** | $\alpha$ | $\rho$ | $\varphi_\pi$ | $\varphi_y$ | $\pi^*$ |
|---|---|---|---|---|---|
| **Estimates** | 0.54*** | 0.85*** | -0.42 | 1.68*** | 2% |
| **Model Assessments** | **Adjusted $R^2$** | **SEE** | **DW stat** | **J-stat** | |
| **Estimates** | 0.90 | 0.29 | 1.16 | 0.32 | |

*This table reports parametric estimates of the forward-looking Taylor-type interest rate reaction function over a sample period from the first quarter of 2001 to the first quarter of 2008. *** indicates the significance at 1 percent level. The instruments included in this regression are the 2 and 4 lagged values of output gap, 1 to 4 lagged values of inflation rates, M0 growth rates, and the OECD crude oil price in logarithm.*

The results suggests that the J statistic cannot reject the null hypothesis at the 95% confidence level that the instruments satisfy the orthogonality condition. It ensures the validity of the Over-identifying restrictions. Additionally, a 90% adjusted R-squared might be a good sign of model fitness. However, the regression is subject to a series of serious problems. First, it is implausible to conclude that the point estimation of the coefficient on Riksbank's interest rate reaction strength to the expected inflation rate deviation is not statistically significant. The Swedish central bank always highlights its commitment to target the inflation at 2% and to maintain the stability of low price. Second, the value of the Durbin-Watson Statistic suggests that there is a high likelihood this model suffers from positive serial correlation.

Nevertheless, the Rikesbank's experiences during the 8 sample years cast strong doubt upon the first hypothesis that the classic Taylor was well performed in Sweden. Such a finding would be consistent with what Gerberding et al. (2005) discovered about the German Bundesbank. Hence, we are motivated to discover why the estimated partial effect of inflation does not pass the significance test, which contradicts the Swedish central bank's policy principle. Reasonably, the under-specification problem might exist in the modeling of Swedish monetary policy exercise in Eq. (5).

As a small open economy that used to defend its currency independence by maintaining an exchange rate, Sweden was concerned with the consequences of integrating into the euro area and sacrificing its economic stability (Sveriges Riksbank, 2009). The extent that Sweden still regards the stability of its currency pivotal to its economic health would be worth exploring. Therefore, a second test of whether the Swedish central bank adjusted its repo rate in response to the exchange rate fluctuation is performed through the estimation of the expanded Taylor-type model Eq. (6). The results are shown in Table 3.

The J statistic again confirms the validity of instrument selection. A three-percentage point increase in the adjusted R-squared compared with the previous results lends more credence to the explanatory power of this expanded model. Evidently, incorporating the expected exchange rate gap into the right hand side of he baseline model and adding four lags to the instrument variable set fine-tuned the serial correlation problem by hiking the DW statistic to a statistically safe range. Furthermore, it is remarkable that all coefficients are significant at the 1% level.

The estimated coefficient of Riksbank's reaction to the expected inflation deviation, 2.22, is three times larger than its response towards the production gap estimate 0.73. This implies a strong inflation-oriented policy, which echoes Sveriges Riksbank's inflation-targeting pronouncement. Based on the estimate $\gamma$ = 0.94, the hypothesized mean of exchange rate TCW index, and an explicit inflation target 2%, the estimate of Swedish long-run real interest rate in equilibrium is 4.30%. This amount is credibly close to the European Central Bank (ECB)'s official estimation of around 4-5% according to 2001 – 2007 statistics (ECB, 2009).

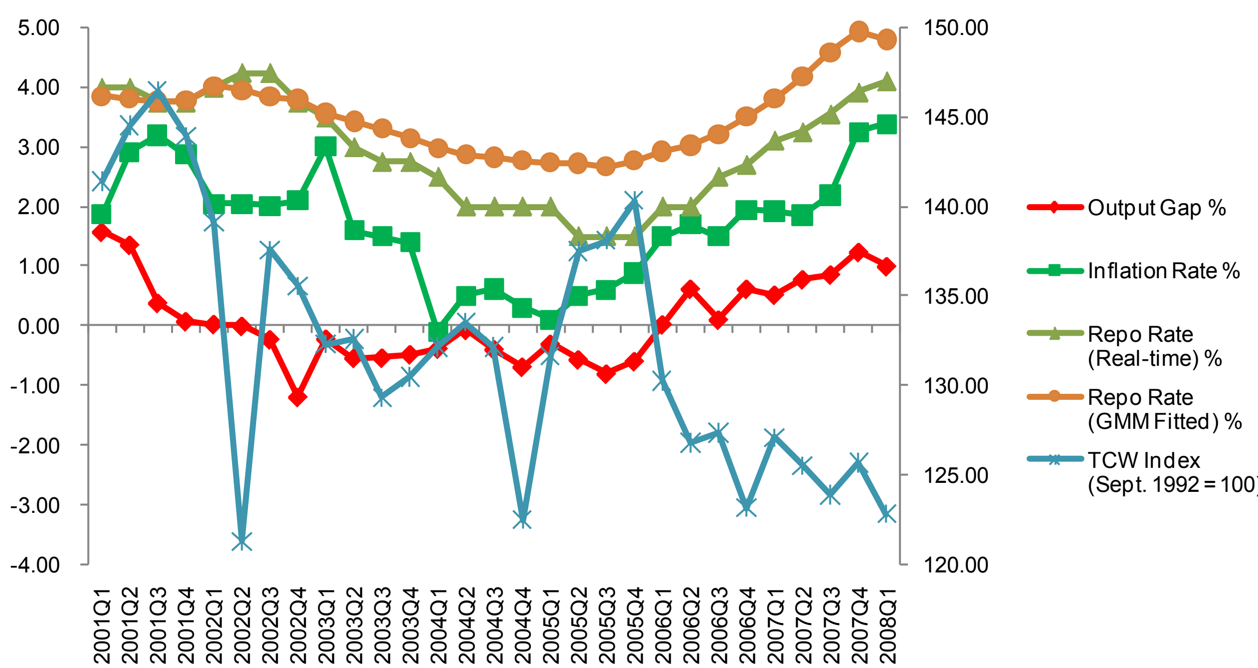
Table 2: GMM Estimation of the Expanded Model - Equation (6)

| Coefficient | $\gamma$ | $\rho$ | $\varphi_\pi$ | $\varphi_y$ | $\varphi_e$ | e* | ř | $\pi^*$ |
|---|---|---|---|---|---|---|---|---|
| **Estimate** | 0.94*** | 0.95*** | 2.22*** | 0.73*** | -0.13*** | 131.53 | 4.30% | 2% |
| **Model Assessments** | **Adjusted $R^2$** | **SEE** | **DW stat** | **J-stat** | | | | |
| **Estimates** | 0.93 | 0.24 | 2.17 | 0.31 | | | | |

*This table reports the parametric estimates of the forward-looking Taylor-type interest rate reaction function – the expanded model over a sample period from the first quarter of 2001 to the first quarter of 2008. *** indicates the significance at 1 percent level. The instruments included in this regression are the 2 and 4 lagged values of output gap, one to four lagged values of inflation rates, four lags of TCW index, M0 growth rates, and the OECD crude oil price in log form. The sample mean of TCW index is131.53.*

Moreover, the significantly negative coefficient -0.13, though small, provides crucial information on the Swedish central bank's interest rate reaction to expected exchange rate volatility. This estimate can be interpreted as, given a certain level of deviation of expected inflation and output, a one point increase in the expected TCW index relative to its mean would induce the Sveriges Riksbank to lower its repo rate by 0.13 percentage points. In other words, the anticipated depreciation of Swedish Krona was associated with a downward adjustment of the Swedish nominal repo rate. Interestingly, Sveriges Riksbank never announced a similar exchange rate targeting policy after abandoning the long-guarded exchange rate regime. However, the evidence does reject our null hypothesis that the central bank spared no effort to maintain the domestic currency stability under the floating exchange regime by adjusting the repo rate.

Figure 2: Policy Inference from Model Estimation: 2001Q1 – 2008Q1




*This figure presents an empirical framework for model explanations by showing how the actual deviation of repo rate adjustment from the model benchmark might be associated with the inflation and exchange rate volatilities in Sweden.*

It is clear that the inflation was well managed during the periods from 2001 to the first quarter of 2003 as it was bounded within the acceptable bandwidth between 1% and 3%. Meanwhile, the real repo rate was tightly controlled and the fitted data via the well-performed model Eq. (6) well captures the actual trend of repo rate development. Noticeably, Krona severely appreciated since 2001q3. According to the fitted path of repo rate growth suggested by Eq. (6), it implies that if the appreciation was anticipated, the repo rates should be mildly adjusted upward. However, it turned out the actual repo rates in 2002q2 and 2002q3 experienced an over-adjustment that simultaneously coincided with a dramatic exchange rate fluctuation, an unsuccessful case of repo rate maneuver. Unfortunately, while the Swedish economy again was confronted with the currency appreciation pressure since 2002q4, the repo rate dropped as conflicting a positive rise recommended by the expanded Taylor model. However, since the domestic price level simultaneously increased, the repo rate should be upward adjusted as implied by the model as well. Thus, the conflicted movement effects could be discounted so that actual repo rates matched the fitted repo rates during the periods 2002q4 and 2003q1. It concludes that the inflation and exchange rate volatility was well harnessed between 2003q1 and 2003q2 too.

Disinflation was getting worse since 2003q2 when the repo rate was supposed to be lowered. However, the actual repo rate adjustment an overreaction. The lower level of the actual repo rate compared to the fitted interest rate might be responsible for the failure of interest rate operations. This not only failed to retain the price level at the 2% target but also could have provoked the roaring of domestic exchange rate between 2003q2 and 2005q4. Hence, the improper manipulation of repo rate might be a crucial reason for ongoing economic volatility during that period. Nonetheless, this story did not end immediately. Though the repo rate began to increase, repo rates could still be considered too low to bring the increasing interest rate to a predicted benchmark. Consequently, the central bank failed to achieve price stability and could have entailed the inflation accumulation and Krona appreciation.

## CONCLUSION

The time-series analysis Sweden suggests: 1) the classic forward-looking Taylor rule, by which the short-term nominal interest rate is adjusted in response to expected inflation deviations and output gaps, is insufficient to capture the Swedish Sveriges Riksbank's interest rate exercise for inflation control from 2001 to 2008. 2) Evidence shows that Riksbank initiated additional efforts, though smaller and obscured, to cope with the volatility of the Krona. Thus, the Swedish central bank is more likely to implement an expanded or locally adjusted Taylor Rule as its interest rate operation method for monetary policy. The Swedish repo rate adjustment aimed at domestic price stability while simultaneously reacted to the expected output gap and exchange rate variation. 3) For a small open economy like Sweden, the reason interest rates could be manipulated in partial response to exchange rate fluctuations might be attributed to the fact that the interest rate is crucial for stability of the domestic currency.

Evidence during the eight-year time span informs us that the Swedish central bank did not effectively bound the domestic inflation in most of the periods or the underlying exchange rate concern barely contributed to the stability of its currency valuation. Two explanations may shed light on how we may evaluate the Sveriges Riksbank's interest rate operation practice.

One explanation is a failure of the expanded Taylor rule practice. Then the classic Taylor rule by which the interest rate should solely react to expected inflation and output gaps without any other policy concern such as exchange rate volatility should be a competitive candidate for a more efficient monetary policy. A supportive argument is that the extra manipulation of interest rates to achieve exchange rate stability may simultaneously sacrifice monetary control (Aguilar et al., 2002). Therefore, the loss of monetary control might further deteriorate the fundamentals of a real economy such as the domestic price level, which may create a dilemma for the central bank. They may need to make compromises between inflation and exchange rate targeting. The positive effects of the interest rate adjustment to control the inflation could be partially downgraded. Consequently, the central bank's capability to inflation target could be negatively affected. It is still cautious to jump into this conclusion because previous literature demonstrates that a strong reaction to the inflation gap is empirically effective in controlling inflation. It may never justify that other reaction considerations are redundant for inflation control.

A second explanation is a theory of the advent of a worldwide economic disorder. The reason why both inflation and exchange rate targeting did not work in the last sample period might be attributed to the fact that the last three years in the first decade of the 21$^{th}$ century called for global macroeconomic instability and financial crisis. This might aggravate the real economy of a country and severely impacts small open economies that are associated with more economic disturbances brought by global chaos. Repo rates might have been set too low in comparison to the benchmark proposed by the policy rule. This can be partially explained by the argument that people's forecast errors gradually accumulated because of an unawareness of the approaching economic crisis that in turn misinformed policy implementation. Therefore, the poor policy performance is simply attributable to the imprecise adjustment of the repo rate in response to the forecasted inflation rate, output and exchange rate deviations.

Further research should examine what analytical framework the central banks' interest rate reactions to the exchange fluctuation may be justified or needless and to what extent the global economic disturbances affected the interest rate operation efficiency.

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